AUTOMATIC RECOGNITION AND REPRESENTATION OF DOCUMENTS

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ABSTRACT

Automatic recognition of the content of documents yields a form of compression for document transmission and archival, and provides a high-level representation with which to manipulate the document. The ease with which a document can be manipulated depends on the representation of the components of the document and on the ability of the recognition system to produce a set of meaningful components. Ideally, a document is segmented into component regions containing text, line drawing graphics and pictures. The text is converted to character codes and related text format information. The line drawing graphics are translated into graphics primitives, and pictures are optionally processed by half-tone screen detection and removal. These outputs are then translated into a document representation language, which also describes the layout structure of the document. In order to study issues in the design and use of document recognition systems, we are building a testbed system. It consists of a text/graphics segmenter, a structure analyzer which groups these segments into higher level concepts, the Kurzweil Discover (a multi-font character recognizer and format analyzer), and a module which translates these outputs into the document representation language, Maker Interchange Format (MIF), used by the Frame Maker publishing system.

1. Introduction

The task of a document recognition system is to convert the scanned image of a document into a representation language which models the original document as accurately and concisely as possible. Automatic recognition and representation of the contents of a document is an alternative to storing the document as a bitmap image. Not only does it greatly reduce the storage requirements, but it allows manipulation of the document in ways which would be impossible with only the image. Alterations of a bitmap document are limited to cut, paste and scale operations. To correct the spelling of a word would be difficult, particularly if the incorrect spelling had too few letters. On the other hand, a document which is described in a high-level language can be modified by editing text and graphics and by moving components to alter the layout. In addition, it allows automatic indexing for filing, storage and retrieval.

Document recognition comprises segmentation and classification of regions of text, line drawing graphics and pictures, and translation of this information into a document representation language. A segmenter classifies possibly overlapping rectangular regions of text and graphics, and a structure analyzer translates these regions into higher level descriptions such as columns of text and lines of text on graphics. Text is translated into its ASCII equivalent, and format characteristics such as font type and size, paragraph breaks, line spacing and centering are detected. Graphics recognition is performed to identify the graphics primitives [Henderson86]. Pictures are processed to detect possible half-tone screening, allowing data compression and optimal rendition on different output devices. These outputs are then translated into a document representation language. In this form, the document can be easily edited, stored or transmitted.

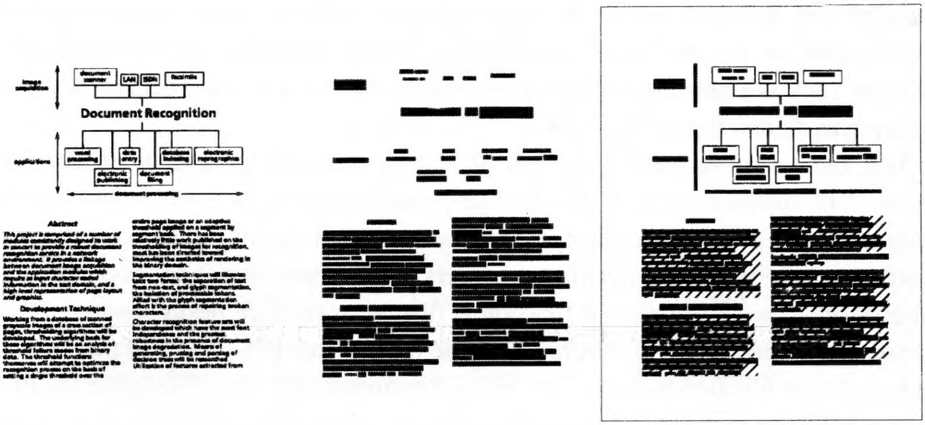
We currently limit ourselves to recognition of the layout structure of the document. That is, we attempt to recognize only the way the components of the document are placed on the page. We do not try to infer the meaning or the logical structure of the document from the set of recognized components. For instance, we do not try to interpret a line of text at the top of a document as a header or title, but simply declare it a line of text at a given location.

Commercial systems exist which provide subsets of the functionality required in a document recognition system. The Kurzweil Discover [Kurzweil87] can convert text to ASCII and recognize certain format characteristics, but cannot automatically handle mixed text and graphics or multi-column text. The GTX [GTX87] vectorization system can perform limited graphics recognition. The Frame Maker [FrameMaker87] publishing system can import text and bitmap graphics, and contains a set of tools for WYSIWYG editing. It also has a language for document representation, the Maker Interchange Format (MIF). However, none of these systems are capable of working together.

Several researchers are investigating aspects of the document recognition problem. A goal of the ESPRIT project HERODE [Meynieux86] is to test the adequacy of the proposed international standard document representation language ODA [Horak85] by using it as the target language for their document recognition system. Kida et al. [Kida86] describe a network-service document recognition system which allows users to edit a recognized file at their workstations, but no mention is made of structure recognition or document representation. A system described in Wong et al. [Wong82], discusses an interactive method for segmentation and character recognition. Srihari and Zack [Srihari86] discuss a method for the segmentation and labeling of document image components.

This paper discusses the current state in our development of a document recognition system. Our design methodology for this system is organized around a cycle of prototyping, experiment and theory development. Our prototype is a modular testbed which allows us to perform experiments while simultaneously working on the

Figure 1: *the original document (a), lines of text (b), and blocks of text, lines of text, and graphics (c)*



theoretical aspects of document recognition. We will describe the following components of our testbed: the segmentation algorithm which separates text and graphics, the structure analyzer which uses this information to infer a higher level description of the layout structure of the document, the integration of the Kurzweil character recognition system and format analyzer, the selection of a document representation language, and the procedure for translating the recognized components into the document representation language.

2. Segmentation and structural analysis

2.1. *Segmentation and classification*

The segmenter identifies rectangular regions of the document and classifies them as either a text line, a text block, or a graphics block. Our current system does not distinguish between line drawing graphics and pictures: all nontext regions are labeled graphics and treated as a bitmap image. A text block is defined as a set of equally spaced lines of text with left justification and approximately equal length. In order for the requirement of equal spacing to be meaningful, a text block must have at least three lines. A text line is an isolated line of text, or a line of text not meeting the text block criteria. The distinction is made between text lines and text blocks because a block of text can be treated as a single flow of text in which line breaks may be ignored, while line breaks in the text lines of a formula or figure label may be critical. The rectangular regions are allowed to overlap, so that text within graphics is supported.

The document is first described in terms of a list of marks (connected black regions). Individual marks are classified as text or graphics based on their size, complexity and classification of neighboring marks. The formation of text lines is based on the linear (horizontal) adjacency of individual marks which have been classified as text. Thus, with knowledge of the distribution of character widths, an inference is drawn about maximal inter-character spacing. In this manner, adjacent characters are clumped into words. Approximately collinear words with appropriate word-spacing are grouped into lines of text, provided there is no intervening graphic structure, such as a rule or grid. Figure 1 shows the lines of text of the document in (a), displayed as shaded rectangles in (b).

Text blocks are formed from lines of text by detecting periodicity in the line spacing. The autocorrelation of the absolute position of the base of each mark is used to estimate the vertical periodicity. Characters which rest on the baseline contain information on periodicity, while characters with descenders add noise to the information. The autocorrelation function is filtered to enhance peaks resulting from the baseline characters while suppressing noise from descenders. The first peak in the autocorrelation function as well as its expected harmonics are used to estimate the line spacing. Allowance is made for noise to corrupt a single isolated harmonic. Lines whose spacing agrees with the average spacing computed in this way are grouped to form a text block.

Graphics blocks are defined as minimal enclosing rectangles surrounding individual marks previously classified as graphics. If graphic blocks are adjacent or intersecting, they are merged to form a new graphics block and the enclosing rectangle is redefined. Figure 1(c) shows the text blocks of the document in Figure 1(a) as diagonally hatched rectangles, the remaining text lines as shaded rectangles and the graphics in its original form.

2.2. *Structural analysis*

The purpose of the structure analyzer is to infer a higher level structure of the document from the recognized components and their positions. While the position of individual text lines, text blocks and graphics blocks is sufficient to describe the layout structure of the document, a higher level description is preferable for integration with the rest of the system. For instance, the interface to the character recognition module is optimized by sending the maximum amount of text possible. In the case of intersecting text and graphics blocks, the concept of being above is important for layout. In our system, a bitmap drawn over text obscures the text, while the reverse is not true. Levy calls this the 2½ dimensionality of documents [Levy87].

The higher-level components of a document are thus columns of text and text on graphics. Columns of text provide the character recognition module with the maximum amount of text, subject to the constraint of single column data with no graphics. The text on graphics component implies that the text is superimposed on the graphics. The concept of text on graphics is also useful in the document representation language, since it allows later manipulation of the text and graphics as a unit.

Figure 2: *a segmentation tree: leaf nodes are text lines and graphics, intermediate nodes are text blocks, columns of text and text on graphics*

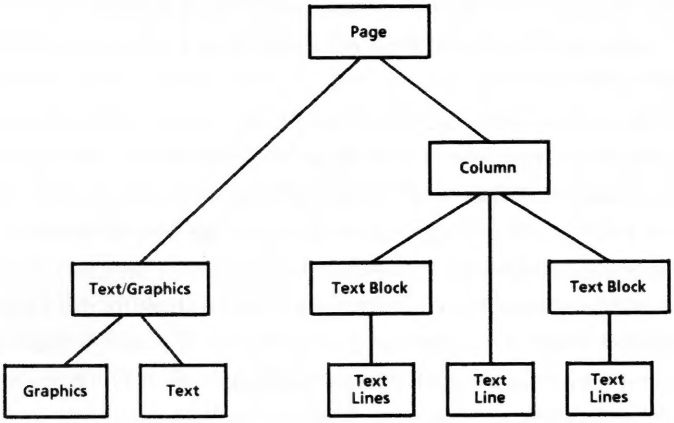


Figure 2 shows the hierarchical representation of a document page. The tree is built from the bottom up, with the segmenter supplying the text lines, text blocks and graphics. Columns of text are built by merging text blocks of approximately equal width (allowing for text set ragged right) that are vertically adjacent and that have no intervening graphics. Lines of text between text blocks, such as titles, should also be included in the column. Therefore, a line of text is redefined as a text block of arbitrary width, and the same rules for vertical adjacency and the exclusion of graphics are applied. Text on graphics is the union of all text blocks or text lines that intersect a given graphics block. The enclosing rectangle for the text on graphics component is redefined as the smallest rectangle enclosing all the text and graphics blocks.

3. Character recognition

The primary job of character recognition is to transform text portions of the scanned document image into their ASCII equivalents. For a system of this type, recognition should be font independent and should require little or no training by the user. By font independent, we mean that the system can recognize most fonts, except stylistic ones, produced by any output device ranging from a typewriter to a laser printer to a printing press. This is in contrast to certain systems, e.g., DEST [DEST87], which recognize only fixed pitch typewriter fonts. User-trained systems require the user to instruct the system as to the identity of each character it sees. Although this mode is useful for applications with large quantities of homogeneous text, we do not see this as practical in a system which expects many different types of documents.

For accurate reproduction of the document, it is also important to recognize the text format characteristics. This includes identification of paragraphs, recognition of font type and size, subscript and superscript detection, recognition of line centering and right justification, and estimation of line spacing and paragraph spacing. Font identification is a difficult task in that it requires examination of detailed characteristics of the text. In fact it is just this level of detail that an omni-font character recognizer wishes to ignore. However, an approximation can be made by recognizing whether the font has fixed or variable spacing.

Work on a font-independent character recognizer based on descriptive features [Spitz87] is in progress. In order to test other components of our system, we are currently using the Kurzweil Discover [Kurzweil87], a multi-font character recognition system which does not require any training by the user. The system performs character recognition and tags questionable and unrecognized characters for ease of later editing. A format analysis mode is available in which format descriptions in the form of escape codes are interspersed with the recognized characters. In addition, a file is generated which gives paragraph profiles for each distinct paragraph type. The paragraph profile file also includes the font descriptions. Our system uses the escape codes to recognize the start and the end of paragraphs, font changes, subscripts, and superscripts. The escape codes also indicate the actual line breaks of the original text and flag hyphens positioned at the ends of lines. We chose to ignore these line breaks in favor of those generated when reproducing the document from the representation language. However, the line break information is used in the translation procedure. The paragraph profiles define the font characteristics of all the fonts used in the paragraph, i.e., point size and whether the font is fixed or variable pitch. The profile also gives the line spacing, spacing above and below the paragraph, and whether the text is right justified or ragged.

4. Document representation language

After the document has been segmented and components of the document have been recognized, the outputs must be translated into the document representation language. This representation should describe the original document as closely as possible in a compressed form. This representation should be such that the document can be easily manipulated by arbitrary editing of text, graphics and layout. If the document is to be shared with other systems, a standard representation for storage and transmission is important.

An international standard for document representation such as ODA [Horak85] is highly attractive. ODA defines simultaneously the logical structure of the document, e.g., titles and paragraphs, and the layout structure of the document, or how it looks on paper [Joloboff86]. Unfortunately, a full implementation of the standard does not yet exist. Another possibility for document representation is SGML [International86], an international standard document description technique developed by IBM. SGML allows markups to be defined which suit the needs of the document, but does not describe how the definitions should be made.

Our current system uses the Maker Interchange Format (MIF) as the document representation language [FrameMaker87]. Although the Maker Interchange Format is not a standard, it is well documented and, as part of the Frame Maker publishing system, includes tools for WYSIWYG document editing, as well as graphics and bitmap manipulation capabilities. MIF allows the user to describe the layout structure of the document and provides for text formatting instructions. Except for the capability of tagging paragraphs and portions of text, it does not provide for description of the logical structure of a document. Maker also has a markup language, Maker Markup Language (MML) similar to SGML. However, it does not have all the capability of MIF. Our decision to use MIF was based on its documentation, its availability, the fact that it runs on Suns, and that it is relatively inexpensive.

The Maker Interchange Format (MIF) describes a document as a sequence of nested rectangular blocks. These blocks contain objects which comprise the document. Graphics objects include lines, arcs and rectangles. Pictures are objects defined by a rectangular bitmap and can be scaled arbitrarily. A text object is either a TextLine, a single line of text, or a TextRect, which is a rectangular column of text. Within a TextRect, text is separated into paragraphs. MIF provides a catalog facility for storing different types of paragraph definitions. Paragraphs are described by type and size of font, spacing before and after the paragraph, and centering. Paragraph definitions are indexed by a paragraph tag. In addition, format within a paragraph can be modified locally, so that, for example, font changes within a paragraph are possible. Groups of objects can be placed into an object called a frame, allowing the objects to be treated as a unit. Frames can be anchored to a location in the text flow or to an absolute location on the page.

Text is placed in the document with the TextFlow statements. TextFlow statements include the identity of the TextRect into which the text is to be placed. Para statements within TextFlow statements indicate either the paragraph tag or explicitly define paragraph characteristics. ParaLine statements within Para statements contain the actual text, as well as local font changes.

If the text in the TextFlow statement is too long for the TextRect, one of two things can happen. If the TextRect contains a pointer to the next TextRect, indicating the direction of the text flow, the text goes there. Examples of this are text flow between two columns of text, or text flow to the next page. In the absence of a next TextRect, the text is "hidden" and can be seen if the TextRect is enlarged, if the font size or line spacing is decreased, or if the next TextRect is added to the TextRect statement. A portion of the MIF code for the document in Figure 1, describing the placement of columns and the text "Abstract," is shown in Figure 3.

Figure 3: *Maker Interchange Format for part of the document in Figure 1a*

```
<TextRect
<ID 1>
<BRect 1.17" 5.58" 3.25" 4.42">
> # end of TextRect
<TextRect
<ID 2>
<BRect 4.50" 5.50" 3.42" 4.08">
> # end of TextRect
<TextFlow
<TextRectID 1>
<Para
 <Pgf
  <Font
   <FFamily 'Helvetica'>
   <FSize 14>
  > # end of Font
 > # end of Pgf
```

```
 <ParaLine
  <TextRectID 1>
  <String 'Abstract '>
 >
> # end of Para
<Para
 <Pgf
  <Font
   <FFamily 'Helvetica'>
  > # end of Font
 > # end of Pgf
 <ParaLine
  <String 'This project ;s compr;sed ofa numberof '>
 >
 <ParaLine
  <String 'modules consistently designed to work in
```

5. Implementation

The image is first scanned at 300 dpi and passed to the segmenter and structure analyzer. The output of these modules is a tree description of the document as shown in Figure 2. Each node describes a portion of the document by defining its type and its location. Types of nodes are page, column, text on graphics, text block, text line and graphics block. The location is given by the upper left corner, the width and the height of the rectangle enclosing the data for that node. The tree is traversed, and appropriate action is taken at each type of node. At a column node, the portion of the bitmap image corresponding to a column of text is passed to the character recognition module, and the recognized data and format information is returned. There is no need to pursue further branches from a column node. At a text in graphics node, the tree is traversed to each of the text branches, and the data from the character recognition is obtained. At a graphics block node, a new bitmap is cut from the old bitmap so that the new bitmap contains only the graphics within the bounding region.

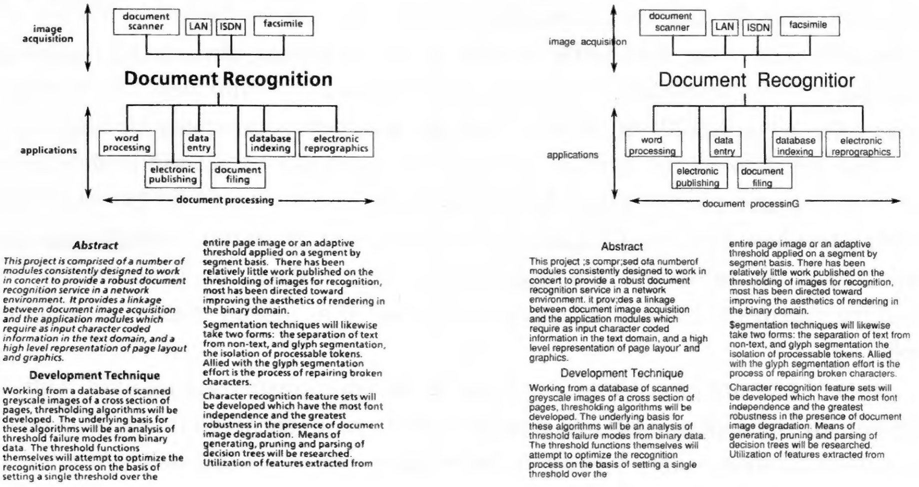
To translate the components recognized above into the document representation language MIF, we again traverse the document description tree. For a column of text, the MIF TextRect structure is created at the appropriate position on the page. Then a table of font statements is made from the font information in the paragraph profile file from the character recognition format analysis. Next, the paragraph profiles are translated into MIF paragraph format descriptions, tagged, and placed in the paragraph catalog for later reference. Information given here includes line spacing within the paragraph, before the paragraph and after the paragraph, font information, justification and centering. Then, a TextFlow statement is generated to incorporate the actual text. The TextFlow statement first indicates into which TextRect the text should be placed, and then gives a sequence of Para statements. A new Para statement is generated when the escape code from the character recognition module indicates a new paragraph. The Para statements contain a tag indicating the correct paragraph description from the paragraph catalog, and a sequence of ParaLines. The ParaLines contain the actual ASCII text. A new ParaLine statement is generated for each line of text from the character recognition, although the actual line breaks will be determined when the document is formatted. Additional ParaLines are needed for format changes within a text line. Thus escape codes from the character recognition module indicating font change, or subscripts and superscripts, are translated by generating a new ParaLine statement. The font information is obtained by lookup in the font definition table.

Lines of text are placed into TextLines at the appropriate page location, with the appropriate font type and size. At a graphics node, an unanchored frame is created at the correct location, with a pointer to the bitmap graphics for that node. At a text on graphics node, a frame is first created to group the text and graphics. This allows the text and graphics to be manipulated as a unit. Within the frame, another frame is created for the graphics at the proper location with a pointer to the bitmap graphics. The text is then placed in TextLines or TextRects within the outer frame. In order for the text to appear on the graphics, Maker requires that the graphics be drawn before the text.

As mentioned before, the character recognition module cannot give the exact font type. Rather, it gives an estimate of the size of the font and whether is is fixed or variable pitch. Our system then uses the nearest point size available, and Helvetica for variable spaced text and Courier for fixed space text. This is one of the major problems with the system, since the recognized text rarely fits back into the original text block. If the text is too small for the original block, the result is obvious and can be corrected by either changing the font size or line spacing, or indicating the next block in the logical text flow. If the text is too large for the given block, a message is given to the user, since the "hidden" text may not be noticed without careful reading. Again, the user can correct the problem by changing font size or line spacing, setting the logical text flow direction, or by increasing the size of the text block.

Figure 4(a) shows again the original document in Figure 1. Figure 4(b) shows the results of the document recognition process. Several errors are present: "image acquisition" was detected as a single line of text, font changes such as the bold titles and italics in the abstract are missing, there are undetected errors in the character recognition, both in substitution and spacing, and the text does not completely fill the first column.

Figure 4: *(a) the original document, on the left; (b) the output of the document recognition system, on the right*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document scanner
LAN
ISDN
facsimile
Document Recognition
applications
word processing
data entry
database indexing
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electronic publishing
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document filing
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Abstract

This project is comprised of a number of modules consistently designed to work in concert to provide a robust document recognition service in a network environment. It provides a linkage between document image acquisition and the application modules which require as input character coded information in the text domain, and a high level representation of page layout and graphics.

Development Technique

Working from a database of scanned greyscale images of a cross section of pages, thresholding algorithms will be developed. The underlying basis for these algorithms will be an analysis of threshold failure modes from binary data. The threshold functions themselves will attempt to optimize the recognition process on the basis of setting a single threshold over the entire page image or an adaptive threshold applied on a segment by segment basis. There has been relatively little work published on the thresholding of images for recognition, most has been directed toward improving the aesthetics of rendering in the binary domain.

Segmentation techniques will likewise take two forms: the separation of text from non-text, and glyph segmentation, the isolation of processable tokens. Allied with the glyph segmentation effort is the process of repairing broken characters.

Character recognition feature sets will be developed which have the most font independence and the greatest robustness in the presence of document image degradation. Means of generating, pruning and parsing of decision trees will be researched. Utilization of features extracted from

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6. Conclusions

We have described our current document recognition system testbed. Much remains to be done in improving the existing components. For instance, errors in text/graphics segmentation are not provided for. In the case text is recognized as graphics, the document retains its appearance, but editing flexibility is lost. The more serious error is graphics recognized as text. This causes erroneous characters to be substituted for graphics. We need a mechanism by which poorly recognized characters could be reconsidered as graphics.

We have restricted ourselves to recognition of the layout structure of the document. There remains much to be done concerning the logical structure of the document. One example is the inference of reading order from the text block structure. Although in most cases one could assume a text flow from the bottom of the left column to the top of the right, a document with English on the left and a French translation on the right would be an exception. Other examples include recognition of a document abstract, author and title identification, location of running headers and footers, and footnote detection. This recognition would be made more robust by the inclusion of prior knowledge of a document. A model for including prior information about a document would specify different classes of documents, and assumptions consistent with the class of document could be made.

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